Heart rate recovery in adult individuals with asthma

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Abstract

Slow heart rate recovery (HRR) after exercise is a predictor of overall mortality in individuals with and without cardiovascular or respiratory disorders. No data on adults with asthma are available. The purpose of the study is to evaluate the prevalence of slow HRR in these individuals as compared with those with chronic obstructive pulmonary disease (COPD). We performed a retrospective analysis of baseline characteristics and physiological response to the six-minute walking distance test of stable individuals with asthma or COPD. Slow HRR was defined as HRpeak - HR at 1 minute after end exercise <12 bpm. Individuals with asthma walked significantly longer (median (IQR): 455 (385-512) *vs* 427 (345-485) meters; p=0.005) with a lower prevalence of slow HRR (30.3% *vs* 49.0%, respectively: p<0.001) than those with COPD. Individuals with asthma and slow HRR were older and walked less than those with normal HRR, without any difference in airway obstruction or in disease severity. Multivariate analysis showed that only the difference HRpeak - baseline HR (ΔHR), was a predictor of slow HRR in both groups. More than 30% of adult individuals with asthma may show slow HRR. Only exercise ΔHR but no baseline characteristic seems to predict the occurrence of slow HRR.

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Introduction

The increase in heart rate (HR) with exercise is due in part to a reduction in vagal tone and the recovery of HR after exercise (HRR) is a function of vagal reactivation [1,2]. Slow HRR has been defined as the reduction in HR one minute after the end of exercise from the rate at peak (HRpeak) less than 12 or 14 bpm [3-5].

A slow HRR is a predictor of overall mortality in individuals with and without cardiovascular [3,6-9] or respiratory disorders [4,10]. In individuals with chronic obstructive pulmonary disease (COPD), a slow HRR after the six minute walking test (6MWT) was associated with an increased risk of acute exacerbations [11]. Therapeutic interventions like exercise training or oxygen supplementation have been shown to be able to improve autonomic nervous system (ANS) function and HRR in individuals with COPD [12,13].

A recent study [14] in children with asthma showed a significantly slower HRR when compared to healthy peers. However, at the best of our knowledge, no data on adults with asthma are available. The detection of the risk of slow HRR after exercise and its prediction might improve the clinical management (e.g., exercise training programs). Therefore, the aim of this study was to evaluate the prevalence of slow HRR (defined as post exercise reduction in HR ≤12 bpm) in adults with asthma as compared with individuals with COPD. As secondary objectives we evaluated the characteristics of individuals with slow HRR.

Materials and Methods

Ethics statement

This retrospective study was approved by the Ethics Committee of Istituti Clinici Scientifici (ICS) Maugeri IRCCS (#2279). As a retrospective study, individuals did not provide any specific written informed consent, however at admission they signed, in advance, an informed consent for the scientific use of their clinical data. As a retrospective, the study was not registered.

Patients

We evaluated the medical records of stable adults with asthma or COPD, consecutively admitted for rehabilitation between January 2019 and April 2021 to the Respiratory Unit of ICS Maugeri IRCCS, Hospital of Tradate, Italy, a referral institution for rehabilitation, diagnosis, and care of post-acute and chronic conditions [15,16]. Data were collected through the hospital informatics system and integrated with data from medical records.

Inclusion criteria were: age ≥18 years; confirmed diagnosis of asthma or COPD according to Global Initiative for Asthma (GINA) [17] or Global Initiative for Chronic Obstructive Lung Disease (GOLD) [18] guidelines respectively; clinical stability as assessed by absence of symptoms warranting change in drug therapy in the previous 30 days; availability of results of and physiological response to the 6MWT performed at admission.

Exclusion criteria were: asthma-COPD overlap syndrome [19]; occurrence of chronic respiratory failure, need of long term oxygen therapy; orthopaedic or neurological diseases preventing the execution of exercise test.

Measurements

The following data and measurements were collected at admission:

- demographics, anthropometrics, diagnoses of asthma or COPD, main comorbidities as reported in the personal medical history, chronic drug therapy.
- Health status by means of the COPD Assessment Test (CAT) [20,21]. The CAT score ranges from 0 to 40 (higher scores indicating a more severe impact of disease on life).
- Resting (at least 30 min in seated position) pulse rate and oximetry (SpO_2) by a Nonin PalmSAT® 2500 pulse oximeter.
- Arterial blood gases assessed on blood samples from the radial artery with an ABL 825 gas analyser (Radiometer, Copenhagen, Denmark) in sitting patients breathing room air.
- Dynamic lung volumes: according to standards using the predicted values of Quanjer [22,23].
- The 6MWT according to standards using the reference values by Enright *et al*. [24,25], under pulse oximeter monitoring (Nonin PalmSAT® 2500). The following parameters were recorded: ΔHR (HRpeak - baseline HR); SpO2 nadir; exercise induced oxygen desaturation (EID: baseline SpO_2 - SpO_2 nadir ≥4%) [26]. The HRR, was assessed as the difference between HRpeak - HR one minute after the end of the test [27]. Slow HRR was defined as ≤12 bpm. The HRpeak, % maximal predicted was calculated as HRpeak/(220-age)*100.

Statistical analysis

An *ad hoc* Excel form aimed at collecting epidemiological, demographic, and clinical variables was prepared. A descriptive analysis of the variables collected for individuals with asthma and COPD was performed. Heart rate recovery was recorded using a cut-off: ≤ (slow) or > (normal) 12 bpm [5]. Differences in qualitative variables were analysed with a chi-squared or Fisher's exact test when appropriate. Continuous quantitative variables with normal distribution were compared using Student's *t*-test, whereas those with non-normal distribution using Mann-Whitney test. Association between the collected variables and slow HRR was evaluated with a logistic regression analysis; covariates with a p-value less than 0.05 at the univariate analysis were included in the multivariate model. A two-tailed $p<0.05$ was considered statistically significant. All statistical analyses were performed using STATA statistical software version 17 (StatsCorp, Prosper, TX, USA).

Results

Out of 1315 patients admitted in the study period, data of 175 individuals suffering from asthma and 153 suffering from COPD fulfilling the inclusion criteria were included in analysis. The demographic, anthropometric, physiological and clinical characteristics of individuals in study are shown in Table 1. As expected, individuals with asthma showed a higher prevalence of females, were significantly younger, showed a greater BMI, with more than half showing a BMI ≥30 kg/m^2 and suffered from less severe airway obstruction than individuals with COPD. Individuals with asthma walked significantly longer during the 6MWT and showed a significantly lower prevalence of slow HRR than those with COPD (30.3% *vs* 49.0%, respectively, $p<0.001$). Table 2 shows the characteristics of participants according to their HRR. Individuals with asthma and slow HRR were older and walked significantly less than individuals with normal HRR. There was no difference in level of airway obstruction or in GINA severity grades [17]. Individuals with COPD and slow HRR showed lower BMI, suffered from more severe airway obstruction and lower PaO_2, walked significantly less and showed lower occurrence of OSA than individuals with normal HRR. In individuals with asthma, higher exercise capacity, HRpeak, and ΔHR were associated with lower risk of slow HRR. In individuals with COPD, lower levels of PaO_2, higher baseline HR, lower ΔHR, 6MWT, and higher occurrence of OSA were associated with higher risk of slow HRR (Table 3). Multivariate analysis showed that only lower values of ΔHR could predict risk of slow HRR in both groups (Table 3).

Discussion

This is the first study investigating the prevalence of HRR in adults with asthma: at least 30% of these people showed slow HRR, a prevalence significantly lower as compared with individuals with COPD. The only predictive factor of slow HRR was ΔHR for the recruited populations.

It has been reported that children and adolescents with asthma have slow HRR after a field test as compared to their peers, suggesting that asthma leads to ANS imbalance [14]. A slow HRR in individuals with cardiovascular diseases may indicate autonomic dysfunction caused by sympatho-vagal imbalance [6,7]. Sympatho-vagal imbalance, assessed by the analysis of HR variability, was observed also in adults with asthma [28,29]. However, these studies did not report HRR. Studies have shown that slow HRR in children with asthma can predict a worse exercise capacity [30]. In our study, individuals with asthma with slow HRR walked significantly less than those with normal HRR.

It has been suggested that the parasympathetic component of the ANS might be implicated in the pathogenesis of asthma [31,32]. In addition, several studies have suggested the existence of alterations in ANS function following exercise in individuals with asthma as compared to non-asthmatic individuals [33-36]. Cardiac vagal reactivity does indeed appear to be increased in asthma, as demonstrated by the cardiac response to various autonomic function tests [37]. However, other studies have reported a lack of association between bronchial and cardiac vagal tone, and this is in accord with the concept of system-independent ANS control [38].

Unlike young asthmatics in whom the severity of asthma was related to slow HRR [14], the adults seem to not show this relationship.

Our results, in accordance with other studies [39,40] showed that the risk of low HRR in individuals with COPD increases with impaired lung function and other markers of disease severity. No associations were found between low HRR and obesity or OSA in individuals with asthma. In the study by Cholidou *et al*. [41] HRR after the 6MWT was significantly higher between healthy subjects and individuals with moderate/severe OSA: the higher the severity of OSA the lower the HRR was. The treatment with CPAP had a beneficial effect on HRR.

Table 1. Characteristics of participants.

Variables	Total cohort (n=328)	Asthma (n=175)	COPD (n=153)	p-value
Males, n (%)	186 (56.7)	74 (42.3)	112 (73.2)	<0.0001
Age, years	69 (61.5-75.5)	67 (57-74)	71 (65-77)	<0.0001
BMI, kg/m^2	28.7 (24.3-33.6)	30.9 (26.1-35.7)	26.5 (22.8-29.8)	<0.0001
BMI <18.5 kg/m^2, n (%)	9 (2.7)	1 (0.6)	8 (5.2)	<0.0001
BMI 18.5-24.9 kg/m^2, n (%)	86 (26.2)	29 (16.6)	57 (37.3)	
BMI 25-29.9 kg/m^2, n (%)	103 (31.4)	52 (29.7)	51 (33.3)	
BMI ≥30 kg/m^2, n (%)	130 (39.6)	93 (53.1)	37 (24.2)	
Resting HR, bpm,	76 (68-84)	75 (68-84)	76 (69-85)	0.63
PaO_2, mmHg	75.9 (68.5-82.0)	78.7 (72.8-84.7)	72 (66.2-78.5)	<0.0001
$PaCO_2$, mmHg,	36.7 (34.0-39.1)	36.7 (34.2-38.9)	36.7 (33.9-39.6)	0.67
Resting SpO_2%	95 (93-96)	95 (94-96)	94 (92-95)	<0.0001
FEV_1, liters	1.7 (1.3-2.3)	2.0 (1.5-2.4)	1.5 (1.1-2.0)	<0.0001
FEV_1, % predicted	71 (53-87)	80.5 (67-93)	59 (44-74)	<0.0001
FVC, liters	2.8 (2.2-3.4)	2.8 (2.2-3.3)	2.8 (2.2-3.6)	0.862
FVC, % predicted	87 (75-101)	90 (78-104)	84 (71-100)	0.012
FEV_1/FVC, %	64.1 (54.2-71.7)	69.4 (62.4-75.3)	56.4 (43.4-64.7)	<0.0001
Comorbidity				
OSA, n (%)	150 (45.7)	100 (57.1)	50 (32.7)	<0.0001
Cardiovascular disease, n (%)	78 (23.8)	35 (20.0)	43 (28.1)	0.09
Diabetes, n (%)	32 (9.8)	19 (10.9)	13 (8.5)	0.47
Hypertension, n (%)	95 (29.0)	54 (30.9)	41 (26.8)	0.42
Drug therapy				
Inhaler therapy, n (%)	299 (91.2)	168 (96.0)	131 (85.6)	0.001
Antithrombotic, n (%)	124 (24.9)	42 (19.8)	82 (28.7)	0.02
Beta blockers, n (%)	88 (26.8)	48 (27.4)	40 (26.1)	0.79
Diuretics, n (%)	112 (34.2)	60 (34.3)	52 (34.0)	0.96
Calcium channel blockers, n (%)	70 (21.3)	34 (19.4)	36 (23.5)	0.37
RAAS, n (%)	170 (51.8)	93 (53.1)	77 (50.3)	0.61
Alfa blockers, n (%)	16 (4.9)	7 (4.0)	9 (5.9)	0.43
Oral hypoglycemic drugs, n (%)	55 (16.8)	28 (16.0)	27 (17.7)	0.69
Lipid-modifying drugs, n (%)	127 (38.7)	60 (34.3)	67 (43.8)	0.08
Systemic steroids, n (%)	36 (11.0)	19 (10.9)	17 (11.1)	0.94
CAT score	12 (7-19)	12 (6.5-18.0)	12 (7-19)	0.46
6MWT, meters	445 (373.5-500.0)	455 (385-512)	427 (345-485)	0.005
6MWT, % predicted	95.2 (81.5-106.5)	98.3 (87.0-109.4)	90.5 (75.1-101.9)	<0.0001
HRpeak, bpm	108.7 (15.0)	109.7 (14.7)	107.6 (15.3)	0.21
ΔHR: HRpeak - baseline HR, bpm	31 (24-40)	32 (26-43)	30 (22-39)	0.02
HRpeak, % maximal predicted	72.1 (65.3-78.2)	72.3 (65.2-78.1)	71.5 (65.3-78.6)	0.74
SpO_2 nadir %,	91 (88-93)	92 (91-94)	89 (85-91)	<0.0001
ΔSpO_2: baseline SpO_2 - SpO_2 nadir, %	–3 (–2 - –5)	–3 (–2 - –4)	–5 (–3 - –7)	<0.0001
Slow HRR, n (%)	128 (39.0)	53 (30.3)	75 (49.0)	<0.001

Data as numbers (n) and percentage (%), median [IQR], or mean ± SD; COPD, chronic obstructive pulmonary disease; BMI, body mass index; HR, heart rate; PaO_2, arterial oxygen tension; $PaCO_2$, arterial carbon dioxide tension; SpO_2, peripheral oxygen saturation; FEV_1, forced expiratory volume at 1 second; FVC, forced vital capacity; OSA, obstructive sleep apnea; RAAS, renin-angiotensin-aldosterone inhibitors; CAT, COPD assessment test; 6MWT, six-minute walking test; HRR, heart rate recovery.

Table 2. Characteristics of participants according to HRR.

Variables	Asthma (n=175)			COPD (n=153)		
	Normal HRR n=122 (69.7 %)	Slow HRR n=53 (30.3%)	p-value 0.001	Normal HRR n=78 (51.0 %)	Slow HRR n=75 (49.0%)	p-value 0.001
Males, n (%)	49 (40.2)	25 (47.2)	0.39	58 (74.4)	54 (72.0)	0.74
Age, years	65 (56-73)	71 (63-75)	0.02	72 (65-76)	71 (65-77)	0.85
GINA (1-5)						
1	5 (4.1)	2 (3.8)	0.39	-	-	-
2	8 (6.6)	0 (0.0)		-	-	
3	17 (13.9)	9 (17.0)		-	-	
4	44 (36.1)	18 (34.0)		-	-	
5	48 (39.3)	24 (45.3)		-	-	
GOLD (1-4)						
1	-	-	-	16 (21.6)	13 (19.4)	0.13
2	-	-		34 (46.0)	26 (38.8)	
3	-	-		22 (29.7)	19 (28.4)	
4	-	-		2 (2.7)	9 (13.4)	
BMI, kg/m^2	31.2 (26.6-36.6)	29.8 (25.9-33.8)	0.55	27.7 (23.9-32.9)	24.7 (21.5-28.9)	0.004
Resting HR, bpm	74 (68-81)	77 (68-85)	0.51	73.5 (65-79)	79 (71-88)	0.002
PaO_2, mmHg,	79 (71.5-84.4)	78 (74.0-84.7)	0.80	74.3(68.5-79.7)	69.5(65.1-76.8)	0.02
$PaCO_2$, mmHg	36.8 (34.3-38.7)	36.6 (33.9-39.2)	0.91	36.7 (33.9-39.6)	36.7 (33.9-39.9)	0.81
Resting SpO_2%	95 (94-96)	95 (94-96)	0.33	94 (92-95)	94 (93-95)	0.89
FEV_1, liters,	2.0 (1.5-2.4)	1.8 (1.5-2.3)	0.58	1.6 (1.2-2.1)	1.4 (0.9-1.8)	0.03
FEV_1, % predicted	78 (63-92)	84 (68-95)	0.44	59 (47-76)	56 (37-73)	0.12
FVC, liters	2.8(2.3-3.4)	2.7 (2.2-3.2)	0.50	2.8 (2.2-3.7)	2.7 (2.1-3.4)	0.61
FVC, % predicted	90 (78-103)	91 (84-107)	0.43	85 (74-99)	83 (67-102)	0.69
FEV_1/FVC, %	69.5 (62.2-76.1)	68.9 (64.6-73.4)	0.79	59.6 (46.9-65.3)	53.2 (39.9-62.2)	0.006
Comorbidities						
OSA, n (%)	70 (57.4)	30 (56.6)	0.92	33 (42.3)	17 (22.7)	0.01
Cardiovascular disease, n (%)	22 (18.0)	13 (24.5)	0.32	22 (28.2)	21 (28.0)	0.98
Diabetes, n (%)	14 (11.5)	5 (9.4)	0.69	10 (12.8)	3 (4.0)	0.08
Hypertension, n (%)	38 (31.2)	16 (30.2)	0.90	22 (28.2)	19 (25.3)	0.69
Drug therapy						
Inhaler therapy, n (%)	119 (97.5)	49 (92.5)	0.20	67 (85.9)	64 (85.3)	0.92
Antithrombotic, n (%)	24 (19.7)	7 (13.2)	0.30	19 (24.4)	23 (30.7)	0.38
Beta blockers, n (%)	32 (26.2)	16 (30.2)	0.59	21 (26.9)	19 (25.3)	0.82
Diuretics, n (%)	40 (32.8)	20 (37.7)	0.53	26 (33.3)	26 (34.7)	0.86
Calcium channel blockers, n (%)	24 (19.7)	10 (18.8)	0.90	17 (21.8)	19 (25.3)	0.61
RAAS, n (%)	62 (50.8)	31 (58.5)	0.35	42 (53.9)	35 (46.7)	0.38
Alfa blockers, n (%)	5 (4.1)	2 (3.8)	1.00	4 (5.1)	5 (6.7)	0.74
Oral Hypoglycemic drugs, n (%)	19 (15.6)	9 (17.0)	0.82	14 (18.0)	13 (17.3)	0.92
Lipid-modifying drugs, n (%)	6 (4.9)	1 (1.9)	0.68	39 (50.0)	28 (37.3)	0.11
Systemic steroids, n (%)	14 (11.5)	5 (9.4)	0.69	9 (11.5)	8 (10.7)	0.86
CAT score	12.5 (7.0-17.5)	12 (5-19)	0.88	11.5 (6.0-17.0)	13 (8-22)	0.08
6MWT, meters	465 (402-525)	427 (335-493)	0.005	450 (382-501)	395 (315-465)	0.004
6MWT, % predicted	99.6 (89.9-111.6)	94.8 (81.6-103.2)	0.02	95.1 (80.7-105.6)	86.8 (68.0-96.4)	0.002
HRpeak, bpm	111.7 (13.8)	105.2 (15.8)	0.007	109.5 (14.2)	105.6 (16.2)	0.11
ΔHR, bpm	35 (28-44)	29 (22-33)	0.0001	36 (30-41)	24 (17-30)	<0.0001
HRpeak, % maximal predicted	72.7 (65.6-78.6)	71.9 (62.2-76.6)	0.19	71.9 (66.3-79.0)	69.4 (63.5-76.8)	0.08
SpO_2 nadir, %	92 (91-94)	92 (90-94)	0.43	90 (86-92)	89 (85-91)	0.48
ΔSpO_2, %	3 (2-4)	3 (2-4)	0.48	4 (2-7)	5 (3-8)	0.52

Data as numbers (n) and percentage (%), median [IQR], or mean± SD; COPD, chronic obstructive pulmonary disease; GINA, Global Initiative for Asthma; GOLD, Global Initiative for Chronic Obstructive Lung Disease; BMI, body mass index; HR, heart rate; PaO_2, arterial oxygen tension; $PaCO_2$, arterial carbon dioxide tension; SpO_2, peripheral oxygen saturation; FEV_1, forced expiratory volume at 1 second; FVC, forced vital capacity; OSA, obstructive sleep apnea; RAAS, renin-angiotensin-aldosterone inhibitors; CAT, COPD assessment test; 6MWT, six-minute walking test; HR, Heart Rate; HR, peak - baseline HR; SpO_2, peripheral oxygen saturation; SpO_2, baseline – nadir SpO_2.

The prevalence of HRR in our study was evaluated after a 6MWT. The clinical utility of HRR is not dependent on maximal exercise [9]. Authors studied the prognostic utility of HRR in individuals with heart failure after the 6MWT and symptom-limited cardiopulmonary exercise test. The results confirmed that HRR after the 6MWT was a powerful prognosticator that performs similarly to HRR after maximal exercise [9]. The 6MWT was used to study the HRR in individuals with chronic respiratory diseases also by other authors confirming the usefulness of this field test [10,14,27,42].

The assessment of HRR may be useful to evaluate the effects of exercise training. The effect of the exercise training in HRR was studied in individuals with moderate-to-severe patients COPD [12]. After 8-weeks of interval training HRR improved significantly, pre-training HRR being the only variable related to post-training HRR. No study has evaluated the effects of exercise training on HRR in individuals with asthma. In our study ΔHR was the only predictor of slow HRR: this simple and cheap parameter should be always evaluated in the assessment of individuals undergoing exercise training programs.

Conclusions

This is the first study investigating the HRR in adult individuals with asthma: at least 30% of these people show slow HRR, a prevalence significantly lower as compared with individuals with COPD. No baseline characteristic is able to predict this event after a 6MWT. Prospective studies will be useful to evaluate the most useful type exercise (walking vs cycle, incremental vs endurance) to elicit this event in adult individuals with asthma.

Table 3. Relationship of demographic, clinical and physiological characteristics and prevalence of slow HRR in individuals with asthma and COPD.

	HRR in individuals with asthma			
	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Males	1.33 (0.70-2.55)	0.39	1.53 (0.74-3.16)	0.25
Age	1.03 (1.00-1.07)	0.05	1.01 (0.98-1.05)	0.49
OSA	0.97 (0.51-1.86)	0.92	-	-
BMI≥30	0.95 (0.48-1.86)	0.87	-	-
Cardiovascular disease	1.48 (0.68-3.21)	0.33	-	-
FEV_1, %	1.01 (0.99-1.02)	0.52	-	-
PaO_2 mmHg	1.01 (0.97-1.04)	0.76	-	-
Resting HR, bpm	1.01 (0.98-1.04)	0.66	-	-
6MWT, meters	0.99 (0.99-0.99)	0.008	1.00 (0.99-1.00)	0.26
6MWT, % predicted	0.99 (0.97-1.00)	0.09	-	-
ΔSpO_2,%	1.06 (0.92-1.22)	0.42	-	-
HRpeak, bpm	0.97 (0.95-0.99)	0.009	1.00 (0.97-1.03)	0.98
ΔHR	0.95 (0.92-0.98)	<0.0001	0.96 (0.92-0.99)	0.04
HRpeak, % predicted	0.97 (0.94-1.01)	0.09	-	-
	HRR in individuals with COPD			
	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Males	0.89 (0.43-1.81)	0.74	1.24(0.53-2.91)	0.62
Age	0.99 (0.96-1.04)	0.99	1.00 (0.95-1.06)	0.95
OSA	0.40 (0.20-0.81)	0.01	0.43 (0.19-.1.02)	0.06
BMI≥30	0.51 (0.22-1.20)	0.12	-	-
Cardiovascular disease	0.99 (0.49-2.00)	0.98	-	-
FEV_1, %	0.99 (0.97-1.00)	0.10	-	-
PaO_2, mmHg	0.96 (0.93-0.99)	0.047	0.97 (0.92-1.01)	0.14
Resting HR, bpm	1.04 (1.01-1.07)	0.003	1.03 (1.00-1.07)	0.07
6MWT, meters	1.00 (0.99-1.00)	0.007	-	-
6MWT, % predicted	0.98 (0.96-0.99)	0.002	0.99 (0.97-1.01)	0.51
ΔSpO_2, %	1.03 (0.96-1.11)	0.41	-	-
HRpeak, bpm	0.98 (0.96-1.00)	0.11	-	-
ΔHR	0.92 (0.89-0.95)	<0.0001	0.93 (0.90-0.97)	<0.0001
HRpeak, % predicted	0.98 (0.95-1.01)	0.13	-	-

An OR higher than 1 highlights the increased probability of slow HRR in case of exposure to a variable selected in the model, whereas an OR less than 1 highlights the decreased probability of slow HRR in case of exposure to a variable selected in the model; OR, odds ratio; CI, confidence interval; COPD, chronic obstructive pulmonary disease; OSA, obstructive sleep apnea; BMI, body mass index; FEV_1, forced expiratory volume at 1 second; PaO_2, arterial oxygen tension; HR, heart rate; 6MWT, six-minute walking test; SpO_2, baseline-nadir peripheral oxygen saturation; HR, peak-baseline HR.

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